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THE OLDEST KNOWN EARLY TRIASSIC FOSSIL VERTEBRATE FOOTPRINTS IN NORTH AMERICA, FROM ZION NATIONAL PARK, UTAH

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Abstract—The spectacular rocks exposed in the Kolob Canyons District of Zion National Park in southwestern Utah include fossiliferous units of the Early Triassic Moenkopi Formation. The extensive exposures of this formation in the cliffs of the Kolob Canyons provide important information about the early Triassic and contain the earliest Mesozoic vertebrate footprint locality in North America. Regionally, Zion National Park lies at the western margin of the Colorado Plateau, near the transition zone between the Colorado Plateau and the Basin and Range physiographic provinces in the Western U.S. The Moenkopi Formation is Early Triassic in age (248 my-242 my) and is exposed in several areas of Zion National Park including the Kolob Canyons District, which lies in the northwest portion of the park. The Kolob Canyons lie 35 miles north of St. George, Utah and 150 miles south west of Capitol Reef National Park. The Moenkopi Formation is exposed in fault-bounded blocks along the Hurricane fault zone, and represents the Western margin of Pangea.

INTRODUCTION

In the summer of 2004 and spring of 2005 early Triassic footprints were discovered on fallen blocks in the Kolob Canyons District of Zion National Park. The blocks were traced back to the source bed, the track bearing host bed. Two of us (ARCM and JLM) discovered large, loose slabs with multiple tracks and tracks preserved *in situ* at the base of this stratigraphic unit while conducting fossil inventory assessments for the National Park Service.

Footprints are the only evidence of vertebrate animal life thus far from this time period in north, central and southern Utah. During this time when the environment was recovering from the biggest extinction in Earth's history the upper, lower red member seemingly was teaming with invertebrate and vertebrate life. There are two distinct ichnotaxa represented thus far at this Moenkopi locality. These animals portray a wide range of behavior characteristics. The rocks of Zion National Park provide a window to explore this dynamic ecosystem. The upper, lower red member, of the Moenkopi Formation is thought of as a regressive sequence environment and bears evidence of periods of sub aerial exposure. Multiple, staked, rhythmatic beds, containing track horizons in vertical stratigraphic section, attest to fluctuating water levels. Periods of higher water levels are represented by ripple marks and swim tracks, while terrestrial walking tracks preserved with mudcracks attest to lower water levels.

PREVIOUS MOENKOPI FOSSIL REPORTS FROM ZION

Gregory and Williams (1947) reported bone fragments from the Moenkopi "red beds" in Zion National Park. Invertebrates, including the ammonite *Meekoceras*, asteroid starfish and the internal molds of mollusks are found in the Virgin Limestone in the Kolob Canyons region of Zion National Park (Santucci, 2000). While inspecting the collections housed at Zion we examined slabs of Virgin Limestone with trace fossils that appear to have been made by an arthropod and resting traces of the ichnogenus *Astrosoma* (brittle starfish) (DeBlieux and Kirkland, 2003).

GEOLOGY

The Moenkopi Formation of southwestern Utah, with its alternating reddish-brown, white and gray layers documents renewed sedimentation along the western margin of Pangea during the Early Triassic.

During the early-to- middle Spathian, a major transgression deposited deeper water carbonate facies on the shelf eastward and southward. The lower red member and Virgin Limestone Member of the Moenkopi Formation in southern Utah represent the southern extent of the early-to-middle Spathian marine regressive and transgressive sequence respectively (Blakey, 1973, 1977; Hintze, 1988; Dubiel, 1994; Marzolf, 1994; Paull and Paull, 1994; Schubert and Bottjer, 1995; Biek et al., 2000; Boyer et al., 2004).

The Early Triassic lower red member (early Spathian) and the Virgin Limestone Member of the Moenkopi Formation (middle Spathian) are interpreted to have been deposited in coastal and marine conditions. The Moenkopi Formation is bounded by the Tr-1 unconformity at its base and the Tr-3 unconformity at its top (Pipringos and O'Sullivan, 1978).

The marine to peritidal regressive sequence in the upper, lower red member tracksites reported herein occur in the top of the formation approximately 20 meters below a prominent bench of the Late Triassic Shinarump Conglomerate Member of the Chinle Formation. The track horizons are within a 3 m thick interval of gray shales and fine-grained sandstones. Above the track interval the Tr-3 unconformity of Pipringos and O'Sullivan, (1978), separates Early Triassic Moenkopi and Late Triassic Chinle rocks and marks a change from mostly shallow marine to continental sedimentation. The Moenkopi Formation at Zion is comprised of the following Members. In ascending order, the Rock Canyon Conglomerate Member, Timpoweap Member, lower red member, Virgin Limestone Member, middle red member, Shnabkaib Member and the upper red member (Table 1; Blakey, 1973 and 1977; Dubiel, 1994; Marzolf, 1994; Schubert and Bottjer, 1995; Biek et al., 2000; Boyer et al., 2004). These members record a complicated series of shallow-marine transgressions and regressions across a very gently sloping continental shelf. The Moenkopi Formation consists of three transgressive members, the (Timpoweap, Virgin Limestone and Shnabkaib Members), each of which is overlain by an informally named regressive red-bed member (the lower, middle and upper red members) (Blakey, 1973 and 1977; Hintze, 1988; Dubiel, 1994; Marzolf, 1994; Paull and Paull, 1994; Schubert and Bottjer, 1995; Biek et al., 2000; Boyer et al., 2004). A laterally extensive track-bearing unit lies within the upper most portion of the lower red member (Table 1, Fig. 1). Both terrestrial and subaqueous (swim) tracks of *Rhychosauroides* and terrestrial tracks of

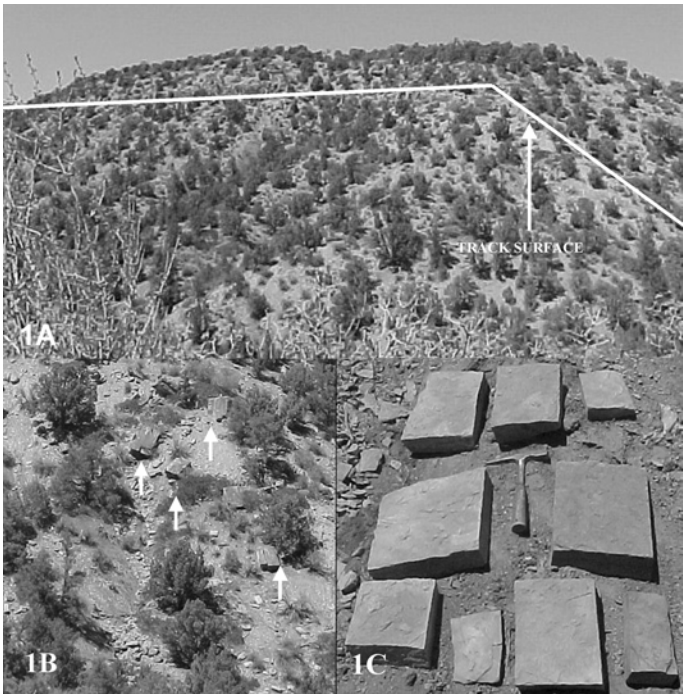

FIGURE 1. **A**, Outcrop of the lower red member of the Moenkopi Formation an extensive lateral track bearing surface denoted by a single horizontal line. The arrow denotes the location where *Rhychosauroides* and *Chirotherium* tracks were collected from. **B**, Arrows denote where *Rhychosauroides* and *Chirotherium* fallen track blocks were collected from in outcrop just below main track bearing horizon. **C**, Fallen track blocks.

TABLE 1. A comparison of stratigraphy of Zion National Park and Capitol Reef National Park vertebrate track localities. *** denotes stratigraphic units with preserved Moenkopi tracks. The upper, lower red member of the Moenkopi Formation at Zion N.P. are the oldest known occurrences of Eary Triassic ichnogenera *Rhychosauroides* and *Chirotherium* (after Schubert and Bottjer, 1995; Boyer, et al., 2004; Biek, et al., 2000; Mickelson, et al., this volume).

SW Utah Zion N.P.	Central Utah Capitol Reef N.P.
Moenkopi Formation	
upper red member	
Shnabkaib Member	Moody Canyon Member
middle red member	
Virgin Limestone Member	Torrey Member ***
lower red member ***	
Timpoweap Member	Sinbad Limestone Member
	Black Dragon Member

Chirotherium exist with in these shales and sandstones. Several morphologic forms of tetrapod tracks and distinctly different "swim" tracks occur in mutually exclusive strata. Regional correlations of the Moenkopi (lower red member) stratigraphic and track bearing horizons at Zion indicate that they are similar to those of the Moenkopi Formation in central Utah. Capitol Reef Nation Park, Glen Canyon National Recreation Area and San Rafael Swell in central Utah, contain extensive track bearing horizons in the Torrey Member of the Moenkopi Formation (Table 1; Mickelson et al., this volume). Comparisons of the lower red member in Zion with the Torrey Member track horizons from central Utah show that each contain abundant, dense concentrations of *Rhychosauroides* swim and terrestrial walking traces and walking traces of *Chirotherium*. The stratigraphically oldest known *Rhychosauroides* and *Chirotherium* track horizons known in North America occur in the upper beds of the lower red member at Zion (Table 1). Slightly younger track-bearing horizons at Capitol Reef, Glen Canyon and San Rafael Swell occur in the middle and upper most beds of the Torrey Member.

VERTEBRATE ICHNOLOGY

Described herein are a wide range of footprints from the upper, lower red member at Kolob Canyons. Swim tracks and terrestrial tracks of small quadrupedal reptiles are abundant. Preserved as positive relief "casts" and negative relief "impressions" are randomly oriented swim traces and complete trackway sequences of walking animals. Tail drag marks and claw marks are very common. Swim tracks indicate that these animals were at least semi-aquatic. Invertebrate marine bivalves and trace fossils indicate that at least brackish water conditions existed.

Walking Tracks

Terrestrial trackways and isolated tracks of *Rhychosauroides* are the most abundant footprint type preserved in the park (site number 42Ws298t). Distinct, well-defined, manus and pes sets are well preserved in linear trackways (Fig. 2; Peabody, 1948; Leonardi, 1987; Tresise and Sarjeant, 1997). Medial tail drag marks, centered between foot falls within the trackway sequence and trackway widths, indicate that this small animal had a fairly wide gait proportional to body length and a body form built low to the ground (Fig. 3) (Mickelson et al., this volume).

Terrestrial tracks of *Chirotherium* are also preserved in the outcrop (Fig. 4). Although, these types of tracks are not very common at Zion they occur as isolated pes footprints.

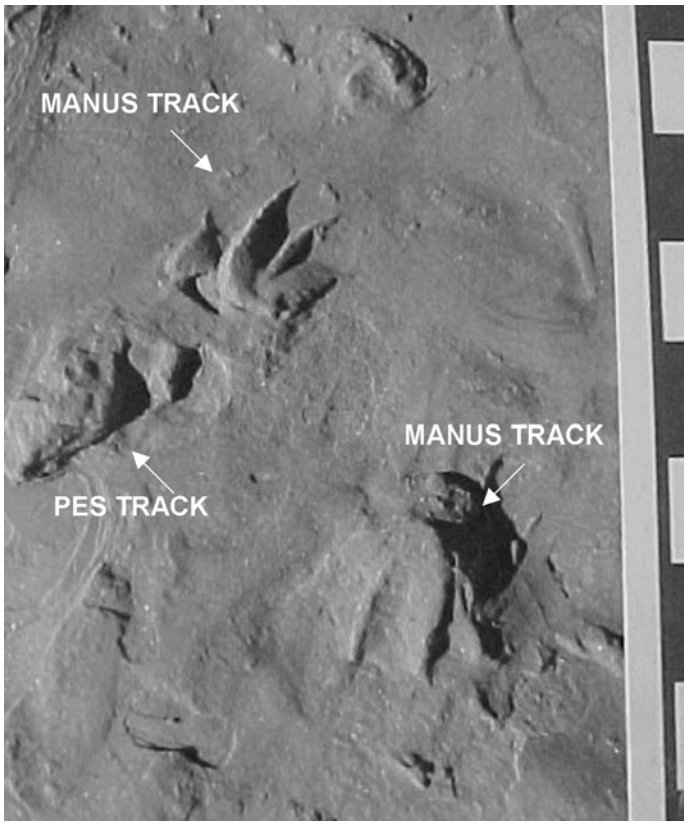

FIGURE 2. An example of ichnogenus *Rhychosauroides* manus and pes set and isolated manus walking footprints, traveling in opposite directions.

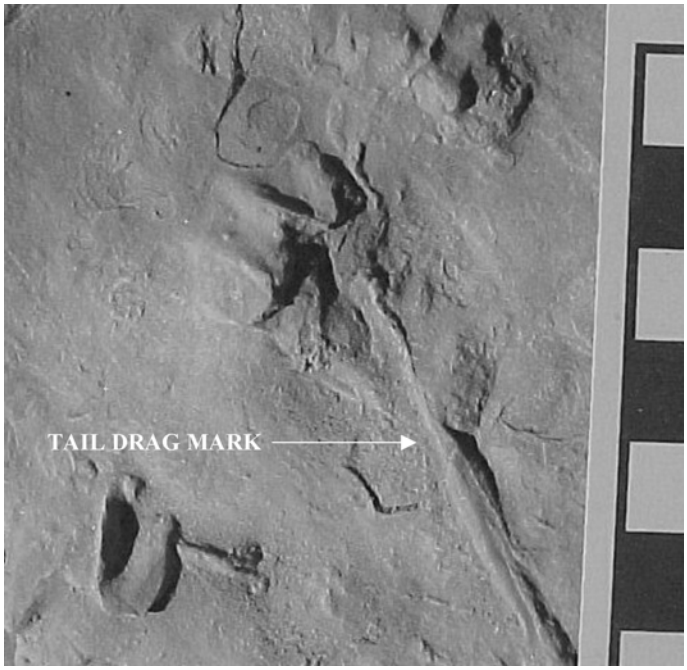

FIGURE 3. An example of a medial tail drag mark of ichnogenus *Rhychosauroides*.

FIGURE 4. An example of ichnogenus *Chirotherium* pes print. The footprint is significantly smaller (5 cm.) than any manus or pes footprints found at Capitol Reef (CRNP), Glen Canyon (GCNRA), and San Rafael Swell areas.

Swim Tracks

Randomly oriented swim tracks are the most common type of swim trace. These traces bear no evidence of forward direction in locomotion. The traces are typically preserved as long, linear, swipes or grooves with two to four digits being represented (Fig. 5). These swipes and grooves formed while the animal was partially buoyant (Mickelson et al., this volume). The second most common types of swim tracks are "toe dinks". These traces are formed at the time the animal was almost fully buoyant and only the tips of their claws were touching the substrate (bottom). These traces suggest that these animals were well adapted to water (Fig. 5; Mickelson et al., this volume).

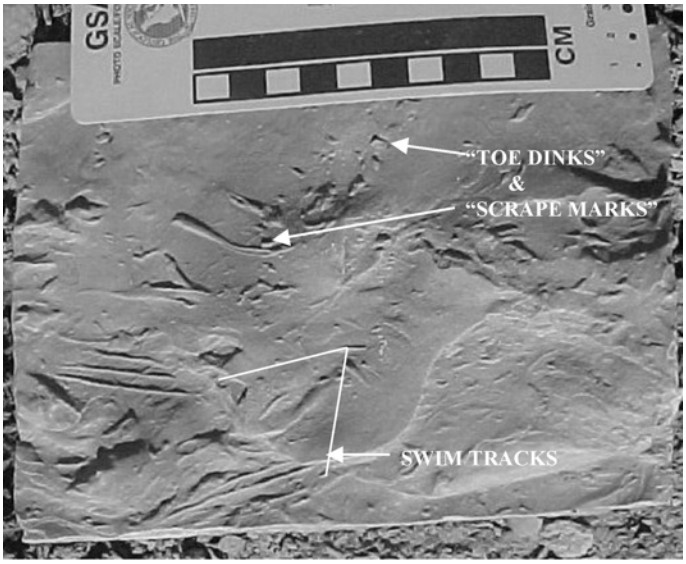

FIGURE 5. An example of ichnogenus *Rhychosauroides* "swim tracks", "toe dinks", and "scrape marks". These types of tracks are dependent upon hip height, water depth and buoyancy of the animal.

DISCUSSION

The vertebrate tracks of the Moenkopi Formation in the Kolob Canyons, Zion National Park all occur within marine regressive deposits of the lower red member. The depositional environment indicates that these organisms were able to tolerate brackish water conditions similar to those of the Capitol Reef National Park and Glen Canyon National Recreation Area vertebrate track localities (Mickelson et al., this volume). More importantly, the lower red member vertebrate tracks are the oldest known Early Triassic footprints in North America. The presence of both terrestrial walking tracks preserved with mudcracks and swimming traces preserved with ripple marks, indicates fluctuating water levels at the time of track deposition. Comparisons of Zion National Park's Moenkopi track bearing horizons to other Moenkopi track horizons in the region provides us an opportunity for lateral and temporal stratigraphic correlations that will help us understand floral and faunal diversity and animal behavior during the Early Triassic of North America.

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